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# Road-Mapping for a Zero-Carbon Building Stock in Developed and Developing Countries

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## Abstract

Given the global climate crises, the enormous construction activity and the rising demand for comfortable living spaces around the world, it is not only the task for today to explore the feasibility of zero-energy buildings based on advanced technology concepts, but also the task for a zero-carbon future to transform the entire building stock. This chapter explores an integrated road-mapping approach to guide the various relevant levels of global, regional and national governance, on sector level as well as on the level of individual buildings. It will explore how key technologies, individual building configurations, infrastructure and the governance framework can be strategically developed in specific market contexts to achieve ambitious performance goals in the given time frame. It also introduces the concept of individual building renovation roadmaps and design features to be prepared in new and existing buildings to enable the retrofit of key technologies when they become economically and technically feasible in the given market. The roadmap approach with a clear performance target and a mid- and long-term vision is paramount since market conditions do not exist yet to implement such buildings in all market situations today. The text presents the concept of transformation roadmaps on the various levels of implementation and introduces examples.

**Keywords:** transformation, roadmap, zero-carbon building stock, governance framework, developing markets, life-cycle approach, future-proof design

## 1. Introduction

We do know today how to design and how to build near-zero-emission buildings. Even plus-energy building performance can be achieved [1] by the integration of highly energy-efficient building design, advanced energy systems and solar energy applications. Under most climate conditions in the world, the annual energy demand and energy generation in buildings can be balanced in the buildings' annual performance, if advanced design principles and technologies are employed, and the ratio between the usable floor area and the solar roof area is not too large [2]. Technically, such performance can be achieved in newly designed, but also in retrofitted buildings. The key technologies are available and technical development

is progressing to make low energy performance buildings more and more feasible in future in all climate zones worldwide.

However, although the global climate crisis is apparent, today only a tiny percentage of buildings is built as near-zero-emission buildings and the existing building stock is not performing anywhere near the required efficiency. In the European Union, at least 75% of the buildings that exist today will still exist in 2050, and only 20–25% will be built new in this period [3]. Therefore, besides the design of new buildings, the retrofit of existing buildings towards zero-emission performance and plus-energy performance is to be pursued throughout the entire building stock worldwide.

While the 2050-building stock is already existing today in the developed countries to a large extent, in other places with currently ongoing urbanisation, new buildings need to be constructed that are able to fulfil the future requirements for low-carbon performance. The low-emission goal is the same, but the starting points and boundary conditions in the various countries are significantly different [4]. Often in rapidly developing economies, where most of the construction activity takes place today, other priorities than the objective to build low-carbon buildings drive this development. Also, the governance framework and the building ordinance are not developed yet, and the local market capacities are not as advanced as necessary to build zero-carbon buildings at the current stage. For example, in many countries, the necessary testing facilities to ensure compliance with high-performance specifications for material, building systems and technical appliances do not exist today [5]. The broad implementation of zero-carbon buildings is also hindered by the available budget for energy-saving investment and other spending priorities. Nevertheless, many clients are aware today that energy prices will rise in the foreseeable future. Also, the connection between fossil fuel consumption for energy services in the building sector and climate change is well known to the clients and the other stakeholders today so that efforts towards advanced performance targets are not hindered by ignorance anymore, but clearly by other barriers.

While a single pilot project is still useful today, the challenge today lies in the implementation of the low-emission performance concepts in the building stock in the markets worldwide. However, there are surely crucial technologies, which continue to be required to be developed, designed and demonstrated in zero-energy building pilot projects in the various contexts around the world. Meanwhile, the effort to transform the global building stock is becoming more process- and policy-oriented, rather than being targeted towards the application of specific technologies and the integration of technology systems on building level. Today, the available technologies need to be rolled out for broad application.

## **2. Contextual conditions**

Technically, the fundamental principles for low energy and zero-energy performance of buildings differ in the various climates. The impact of the various components of the building energy balance will result in different configurations of the physical building systems and the building energy systems depending on the local conditions.

It is also evident that some of these technical configurations while being technically feasible based on international best practice are not economically feasible today and might also overstress the local market capabilities, the skills of the workforce and economic capabilities and the willingness of the local clients to invest in low-carbon design. However, as the building sector is a significant part of all local economies today, with about 30–40% of the national energy demand in

most countries, in order to advance the zero-carbon development, especially the building sector must contribute. The building sectors' development in such contexts needs to be guided since there currently is, and there will be, significant pressure from the urbanisation and the parallel socio-economic development in the available time frame. In order to avoid login effects through unsuitable building design and the omission of required technical provisions under these conditions, the design must be prepared with appropriate foresight to achieve the intended performance if not now then at least in the long run before 2050.

### **3. Development of contextual conditions**

In the assessment of advanced energy concepts besides these conditions of the application of key technologies in each market, also other factors of the market context need to be observed. For instance, under the usual accounting methodology to offset unavoidable emissions, such as for heating in winter or for electricity use in the night with credits for energy generation in times of availability of renewable sources, the assessment will change depending on the change of the emission factors of the delivered energy to the site. Therefore, in a context where clean electricity is supplied by the local grid, building integrated renewable energy systems can contribute less to reduce the carbon account of a building than in a context with emission-intensive energy infrastructure.

As we can assume that the energy mix will move towards a higher percentage of renewable energy sources through the transformation of the national energy infrastructure in many places, the building-related balance calculation needs to be updated regularly over time towards the intended 2050 performance. In case conventional energy sources are used for heating or domestic hot water generation, the results will show that the building's low-carbon performance decreases if the energy consumption is not decreased at the same time, or the building-integrated renewable energy supply is not increased. In other words in situations with emission factors of 600 g/kWh in the local energy mix, 1 kWh renewable energy produced inside the building will off-set double the amount of CO<sub>2</sub> emission from fossil energy carriers than in situations with a carbon-emission factor of 300 g/kWh.

In consequence, while it is essential to reduce the carbon emission factor of the local electricity grid as a strategy on the national and local municipality level, the zero-carbon strategy on building level must reduce the use of fossil energy carriers for building operation through energy-saving measures and in the last consequence by replacing these fossil applications with clean alternatives in the course of the buildings' life cycle.

The feasibility of such alternatives currently rests with the ability to align the time profiles of energy demand and energy supply from alternative energy sources. As renewable sources depend on environmental processes such as wind and solar radiation, storage technologies are needed. There are three possible solutions to this problem, which differ in their demand for infrastructure and investment:

1. Installation of energy storage solutions as public infrastructure to buffer clean feed-in energy centrally and then to supply seamlessly back to the end-users.
2. Installation of energy storage applications as part of the building system to buffer available clean energy until it is used inside the building by the end-user.
3. To adjust the users' demand to the available resources and to accept that not all demands can be met in the building at all times.

These three strategies can be combined in the building's renovation roadmap. Design in a developing market might first rely on a sufficiency approach (option 3), in which the building design can support the best possible functionality and reduce discomfort, but not guarantee the complete set of performance, which could be achieved when energy would be available at all times. Then, option 1 or 2 could be installed later in the buildings' life cycle as a more functional solution when funds and other capacities are available. Also, in the case of the more extended future where central solutions are developed (option 1), an individual approach (option 2) might only be used as an intermediate solution. In all these cases, the original building design needs to be prepared from the beginning to accommodate the necessary change.

A similar situation can be observed in many developing countries for the installation of room conditioning systems for cooling and heating. Traditionally, the building users are used to free-running conditions. In such situations, the users have to adapt to the climatic conditions in order to find comfort. At a later stage in the buildings' life cycle, the comfort demand changes and technology becomes affordable in the given market. In consequence, the retrofit of conditioning systems becomes necessary. As we can foresee such change of demands, the retrofit should be factored into the design from the beginning. The initial design should include sufficient installation spaces in appropriate locations for the indoor and outdoor units, and airtightness of the building envelope and appropriate zoning of the interior spaces must be prepared.

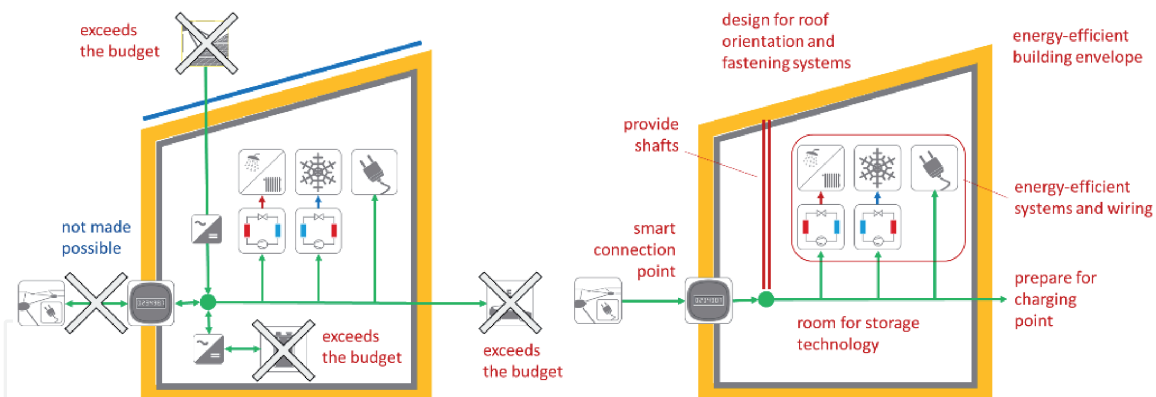
#### **4. Future-proof design**

A future-proof design of buildings takes the long-term goals and developments into account at the time of designing. It is not only considered what can be implemented today, but what is to be added and retrofitted in future to complete the building system in order to achieve the intended performance. Future-proof design can consider future energy retrofit measures towards the projected zero-emission performance, but also other objectives, such as barrier-free design or the extension of the floor space area in case that the occupants' living situation is changing in the building's lifespan.

For instance, "solarisation" of master plans is an objective of master plan development to allow for the installation of functional and economically feasible solar systems. This solarisation would include the orientation of unshaded roof areas to the south, the roof slope, the size and dimensions of roof areas so that solar systems can be fit as well as the location of the buildings in the neighbourhood in case these roofs are planned to be part of a district heating system in future [6]. Such foresight in master planning is essential for solar thermal systems and also to achieve the highest electricity harvest in case of PV installations. Hence, in order to prepare our buildings for future retrofit of solar systems, provisions need to be made. The requirements thereby depend on the context. In situations with low module prices and high energy tariffs (as in Germany), the design of PV systems is not as restricted anymore by economic constraints and therefore building design for integrated PV systems is freer than in situations with high technology prices compared to the available budget and low saving potentials due to low energy tariffs in a given market, such as in Vietnam.

Future-proof design will make provisions for installation of available technologies that are not economically feasible at the time of the first construct, due to high installation cost with the available budget or uneconomic performance due to low energy prices. In many countries and especially in the emerging economies,





**Figure 1.**  
 Zero-emission-ready building design.

energy tariffs are subsidized for economic and social reasons. It can be expected that subsidies are reduced and that energy rates will increase and that at a point in time in the building's lifespan retrofit of energy-saving measures and renewable energy applications will become more feasible and convincing than they are today. An example of future-proof design is given in **Figure 1**.

Future-proof design can also be made in the expectation of future technologies, such as new energy storage systems or new low-carbon fuels. As such systems move up the technology readiness levels in research and development, they will become available for installation in future.

## 5. Road-mapping

### 5.1 Introduction

A technology roadmap is an instrument to outline the expected future development and the boundary conditions of such development. The application of roadmaps built on the hypothesis that the future does not simply happen but can be constructed with a view towards a desirable future [7]. A roadmap helps to align short-term targets with long-term goals and directions [8]. The roadmap also helps to understand the context of technical developments better. A technology roadmap will document the current context and will draft the desired future performance. It will then develop a pathway from the current situation towards the intended future performance. In the original form, a roadmap requires a graphical representation and the time axis to depict the required steps in their sequence towards the desired state. Today, besides the graphical representation, table structures and narratives are used in the development and communication of roadmaps. Such roadmap is not static-once developed and then applied until the end of its time frame- but a roadmap design requires mechanisms for its review and continuous improvement [7].

As instruments for planning for the future and for directing the development towards the desired state, roadmaps have been used on various levels in management, economy and policy contexts. Policy roadmaps and sector roadmaps are used widely today to understand the contexts and requirements of transformation processes on the larger scale of countries or worldwide. In companies, roadmaps are used for product planning, the development of capabilities and strategic knowledge assets and to align activities between departments towards a coordinated goal. Phal et al. [7] list various types of roadmaps as given in **Table 1** and their specific purposes, and obviously, roadmaps can be used for further applications.

Purpose	Description
Product planning	A common type of roadmap, aligning technology and product strategy, typically including more than one generation of product
Capability planning	More suited to service-based enterprises, focusing on the insertion of technology into organisational capabilities
Strategic planning	Includes a strategic dimension, supporting the evaluation of different opportunities or threads typically at the business level
Long-range planning (foresight)	Typically developed at the sector or national level incorporating longer time horizons (e.g., industry, science and policy, foresight roadmaps)
Knowledge and asset planning	Focus on aligning knowledge assets and knowledge management initiatives with business objectives
Programme planning	Focuses on the implementation of strategy, to support the management of integrated R&D programmes. This type is more closely related to project planning methods (Gantt charts)
Process planning	Supports the management of knowledge, focusing on the knowledge flows necessary to support a particular process area, such as new product development
Integration planning	Focuses on the integration and/or evolution of technology, and how different technologies combine to form new technologies

**Table 1.**  
*Types and purposes of roadmaps, cited from Phal et al. [7, p. 16].*

A multilevel approach is required involving the identification of technologies and the technological context, the assessment of its compatibility and the complementary of various technologies and the integration of the technologies into the system as well as the implementation of first implementation instances to introduce new technologies and concepts into a market [9].

Often technology roadmap designs are structured with the layers such as the science layer, the technology layer, the application layer and the market layer (S-T-A-M framework) [7], each addressing one aspect of a product’s life cycle. On a higher level of technology application in the design of a governance framework, the layers social context, technology context, economic context, environmental context, political context, legal context and infrastructural factors could be used. A roadmap can be designed to fit the needs of the specific application. In this chapter, a retrofit plan for a low-emission building is to be promoted with layers along with the main components of the energy balance and the elements of the energy concept.

5.2 Applications of roadmaps

Rockström et al. [8] suggest a global roadmap for rapid decarbonisation. The authors remark the model-based decarbonisation strategies often fall short of capturing transformative change and the dynamics of development involving disruption, innovation and nonlinear change in human behaviour. Therefore, they suggest drafting a roadmap towards the achievement of global decarbonisation based on simple principles, such as halving the anthropogenic carbon dioxide emissions every decade. Such a goal will serve as guide rail with increasing ambition every decade to achieve the required change in steps until the long-term goal is reached.

However, the simpler the roadmap to guide policies, the lesser its use to achieve the goal in the field. We need to translate the goals on the global policy level to national goals in every country and sector goals in every sector in every country. Ultimately, these goals must be applied in every facility and case of the building sector for every existing and newly built building. Rockström et al. [8] structure their

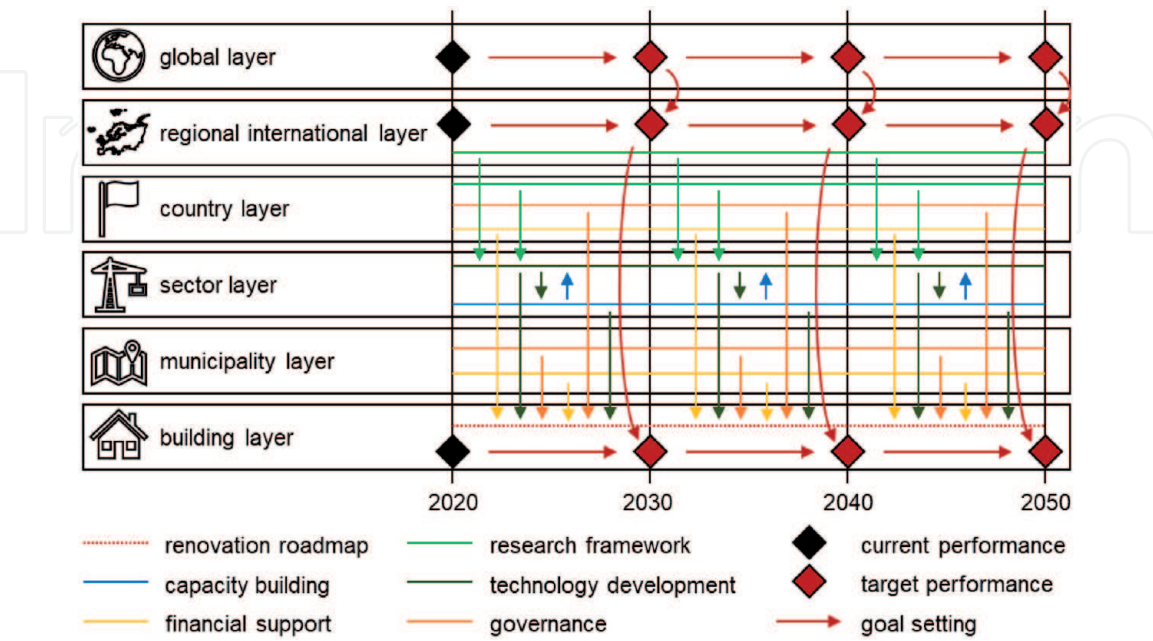
roadmap framework and suggest developing narratives in the dimensions innovation, institution, infrastructure and investment to understand the required conditions and steps in the various sectors. These narratives could be reviewed and newly aligned to the actual development in regular steps. The narratives developed in the various sectors by the sector stakeholders and experts can be used to align actors and organisations to achieve a common goal through trans-sectoral transformation.

In consequence, not only one broad roadmap is required, but countless individual roadmaps are required towards delivering the individual share to the solution. Since all these individual roadmaps are directed towards the same common goal, actions are aligned and are in the best case supportive to each other.

Benefits can be realised through an interplay of the roadmaps on the various levels. For instance, in many situations, the first movers are essential to start the required market transformation, but these first movers often face disadvantages, such as pioneering costs, reluctance in the market and the investment in early technology generations. In such situations, a roadmap on a higher level can provide security for first movers' investment and activity [1], so that the early majority can follow, and the application is taken up by the mainstream. The long-term framework of the German feed-in tariff is an example of such support. Since the feed-in tariff was guaranteed for 20 years, investors were willing to invest in an early generation of solar photovoltaic systems, which in turn provided the market for first movers in the solar industry in Germany and later worldwide.

**Figure 2** depicts the scheme of a layered integrated implementation roadmap towards zero-carbon building performance in 2050. Only the aligned interplay between the layers will allow the stakeholders on the building layer to implement near-zero-emission buildings effectively and to align their efforts towards the same goal. Formulation and communication of the specific roadmaps will allow the individual layers' stakeholders to link into the activity of the other layers in order to contribute to transformative change together.

In the context of building's design and the broader field of urban development, a more elaborate narrative of a desirable future defined by a framework of sustainable qualities and performance characteristics can be formulated. Such a narrative



**Figure 2.**  
*Schematic depiction of the layers of an integrated implementation roadmap framework towards zero-carbon building performance.*



can then give direction for the required development and the communication and alignment of strategies.

In this sense, following the global goal, the requirements set in the Paris Agreement, it is the aim to reduce the carbon emissions of the German building stock towards 0 kg CO<sub>2</sub> emissions till 2050. Such a time perspective provides 30 years to reduce the emission of the building stock by improving the building performance and the performance of the energy infrastructure. However, the activities towards the desired performance must be planned in order to make effective use of the given time. Long-term goal setting will provide security to the market but will also create the required pressure. It will allow all the stakeholders to plan and to start the individual transformation process and will avoid overwhelming the stakeholders by abrupt changes.

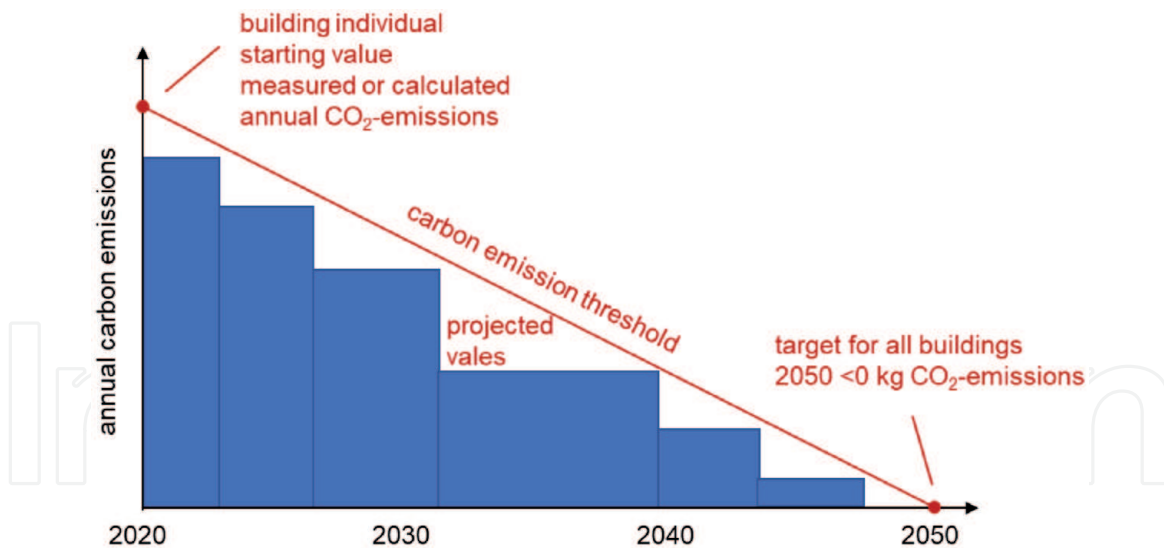
It is possible today to evaluate the performance of buildings before they are built, and the performance of different configurations of retrofit measures can be assessed for the development of a retrofit plan, for example through computational simulation studies. To calculate the future performance, the assessor has to make predictions on the development of economic parameters, such as system costs, energy tariffs and operation cost and environmental impacts, such as the composition of the energy mix and the resulting CO<sub>2</sub> emissions.

In case a roadmap approach is applied as part of a governance framework or for performance assessment in a subsidy scheme, these predictions can be defined by the operating body to support the designers and assessors of the individual building projects. Such a definition of the evaluation context is an example, where the country-level roadmap and the building-level roadmap are interlinked. By defining and providing such context information on a higher layer with the mid-term and long-term perspective, the assessment for single building projects but also higher-layer policy interventions can be supported on the lower layers.

In this context, the German sustainable building council has issued a framework for “carbon-neutral buildings and sites” [10]. Herein, carbon accounting rules, rules for CO<sub>2</sub> reporting and carbon management rules (or a climate protection roadmap) are provided. The framework sets current and future individual performance targets of a building or a group of buildings by assessment of the current annual carbon emissions and the target carbon emission of <0 kg CO<sub>2</sub> emission in 2050. The target values in between are retrieved by simple linear interpolation between the current values and the targeted value, as shown in **Figure 3**. If the building performance remains below this line, and the retrofit roadmap is followed, the building can be labelled “carbon-neutral by 2050”.

Such a roadmap framework will allow preparing for planned future enhancement of the technical installations in the given time frame until the most ambitious target is reached. Since it sets performance targets in terms of carbon emissions, the framework is not restrictive to any technology and operation strategy.

It will allow identifying technology fields that require or allow the installation of advanced solutions immediately and to schedule the retrofit of other solutions in the building’s life cycle. For example, the client could decide to install double-glazed windows today but to schedule the installation of triple-glazed windows in the next renovation cycle in 2040 after the technical lifetime of the first set of windows. At that time, triple-glazed windows might be better available in the local market. Another example could be a building concept that relies on natural ventilation first to reduce the initial cost of construction, but that is prepared for retrofit of a controlled ventilation system with heat recovery in future when such systems are better available from local suppliers. For other technologies with long technical lifetimes, high-performance solutions should be implemented from the beginning. In any case, lock-in effects must be avoided, so that high-performance solutions can



**Figure 3.**  
 Roadmap to the climate-neutral building stock. Reproduced from DGNB “Framework for carbon-neutral buildings and sites” [10].

be implemented at a later time in the building’s lifetime. Therefore, roof spaces must be designed suitable for solar collectors and shafts must be provided to run the required cables and pipes (see **Figure 1**). For some solutions, road-mapping also gives hints where leapfrogging of inferior technologies is required.

### 5.3 Modelling for building assessment

Architects and engineers can model the building and its future performance under the local conditions and test and develop such design variants in the computational thermal building simulation model today. In contrast to the usual application of computational simulation models, the optimisation target is first set to <0 kg CO<sub>2</sub> emission with the anticipated boundary conditions of 2050. A building concept with the desired performance and design qualities in 2050 is developed, and the design is detailed, although not all planned systems are to be installed at the time of first construction. The design is then reduced step by step and solutions for the later retrofit towards 2050 performance are developed. The technical systems are evaluated based on their technical lifetime and the required maintenance, and replacement cycles are considered in roadmap development, thereby retrofit, and energy upgrade steps are scheduled in the period till 2050. The performance of each retrofit step is simulated and evaluated with the anticipated boundary conditions at that time.

In order to apply such a roadmap approach, the assessor will need to make predictions of the development of economic parameters, such as installation costs, energy tariffs and operation costs. The assessor will also have to make predictions on future technical development, the technical and economic lifetime of systems, as well as on the development of the market context. Parameters such as labour cost for installation and maintenance work as well as the available skills for technology installation and maintenance need to be considered. Many of these required assumptions can be provided by central bodies, such as the government, administrations, funding institutions or professional associations to support strategic road-mapping on building level towards the international climate protection goals.

Such central generation and provision of required data would reduce the individual degrees of freedom in modelling and thereby make the modelling results more comparable. The boundary conditions can be supplied from higher layer

roadmaps and agreed and consolidated research results. For instance, the German Ministry of Construction has recently provided new test reference year datasets for the current climate conditions, but also for the climate in 2050 including the predicted climate change effects to be used in thermal simulation studies for future situations [11].

## 5.4 Application in the building sector

An example for the application of roadmaps is the “individual renovation roadmap” (individual Sanierungsfahrplan, iSFP) as it is currently introduced by the German Federal Ministry for Economic Affairs and Energy (BMWE) for the application in energy-retrofit projects in Germany [12]. In future, an iSFP will be the basis for a financial support scheme for the retrofit of building projects in Germany. Before isolated retrofit measures are planned, an individual renovation roadmap is drafted to define the intended development of the building’s functions and performance. In this way, it is possible to avoid lock-in effects and to make use of synergies in the energy system of the building. The method is explained in detail in the “Handbuch für Energieberater” [12] in relation to the existing building assessment framework in Germany.

Also, the subsidy schemes in Germany support the preparation for renewable energy retrofit. In one programme, investment grants are provided for “renewable ready” condensing boiler systems in case these systems are prepared for later renewable energy integration with prepared additional fittings for necessary piping and functions in the control system. Investment grants are paid to the investor if the renewable energy system is installed within 2 years after the installation of the heating system.

Also, the US Department of Energy has developed a “Zero Energy Ready Home” [13] building labelling system, which builds on top of the existing and forthcoming low energy building requirements and requires the client to prepare for the later retrofit of renewable energy systems. Within the scheme, the client has to demonstrate that the maximum allowable loads of the roof structure are sufficient for the installation of PV solar collectors, that the conduits run from the roof to the dedicated location of the inverter and that the inverter can be connected to the electrical panel and circuit breakers are prepared for installation.

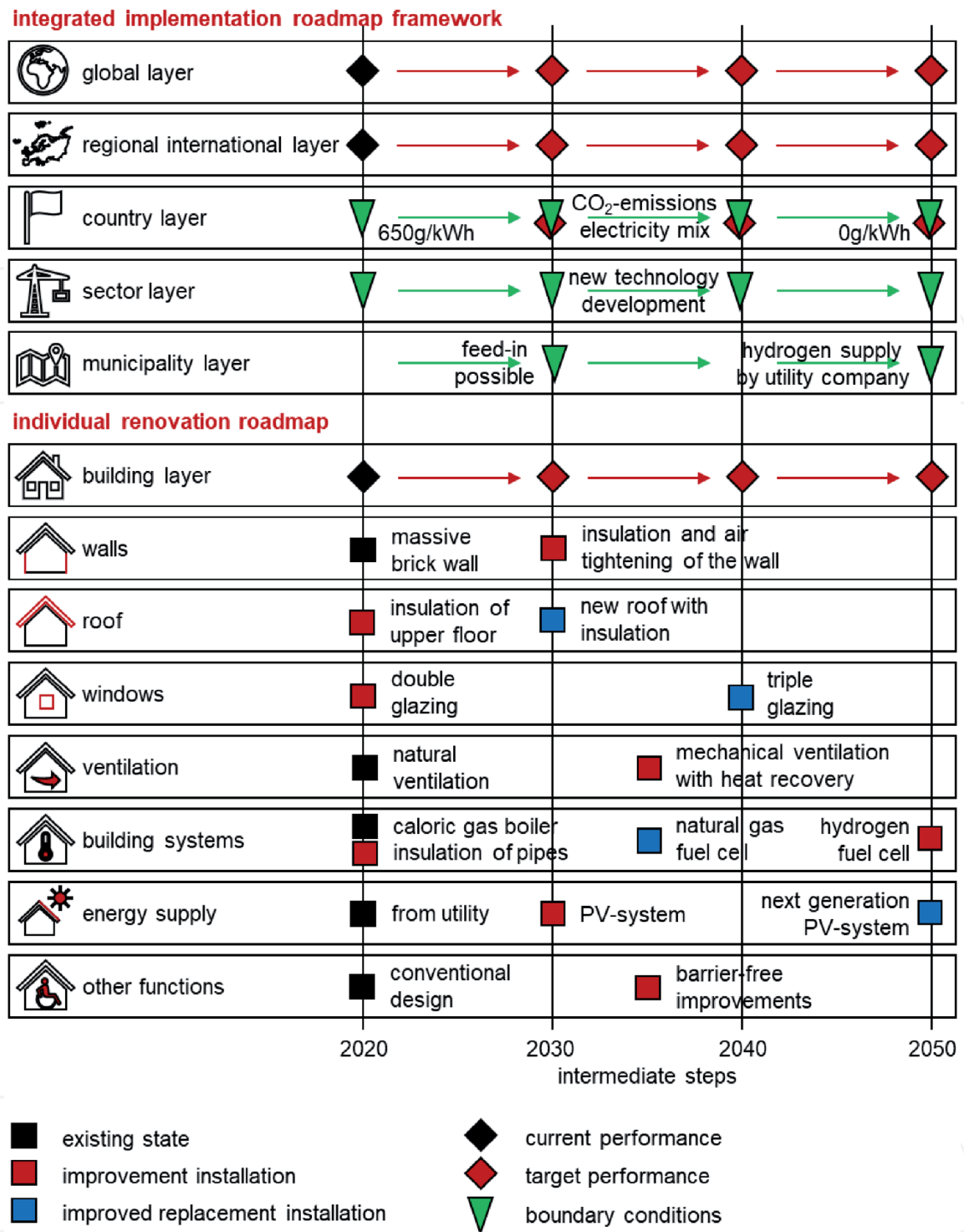
Since in many situations, the current building practice is too remote from the intended performance, such as plus-energy performance or zero-carbon performance, a roadmap approach will be instrumental for the development of the building stock in many countries.

## 5.5 Steps in the individual renovation roadmap

In summary, the following will draft the steps in the integrated and the individual renovation roadmap. The concept is illustrated in **Figure 4**. It is suggested to develop narratives and technical concepts for the state of the art, the goal in 2050, the situation today and of intermediate steps.

### 5.5.1 State of the art

In the development of roadmaps for a zero-emission building in a specific context, state of the art needs to be reviewed and currently available advanced options for retrofit are to be listed. Thereby the commonly used technologies, as well as the local and international front runner technologies, need to be addressed to benchmark the current and the possible future performance.



**Figure 4.**  
*Illustration of individual renovation roadmap under the influence of the integrated implementation roadmap layers.*

The review of state-of-the-art technologies will inspire the designers for the design of the building today and envision the developments of potential key technologies in future. Thereby, a front-runner technology review and the review of technology development, which are currently still on the low end of the technology-readiness level scale of research projects, are very informative.

5.5.2 2050

The performance goal defines the “2050” narrative and the intended performance. In the case of the DGNB roadmap to climate-neutral building stock, it is a



total annual carbon-emission of 0 kg. Also, the technical configuration of the building and the boundary conditions for the calculation need to be specified in order to be useful for the building owner. The configuration able to achieve the intended performance can be determined through computational simulation. The technical description is the target for the successive retrofit.

### *5.5.3 Situation today*

Today's state of the building is either in case of building retrofit projects the current condition of a building at the time of assessment or it is the state of a new building at the time of construction in case of a newly built building. This condition is documented as the starting point for roadmap development.

In order to design a "climate-neutral by 2050" building, it is advisable to determine the 2050-configuration first and then to subtract the elements until construction is technically and economically feasible at the current time. The subtraction of elements can be due to financial constraints, or due to technical availability or market maturity or also due to changing demand. Obviously, it is not possible to predict the future precisely, but the road-mapping approach will help to avoid lock-in effects and allow for the design of future-proof buildings.

### *5.5.4 Intermediate steps*

The intermediate steps are defined by the current state and the intended state in 2050. In the method introduced earlier, these intermediate steps are determined by subtraction components from the high-performance configuration. In this process, the technical lifespans of the building components and service systems are considered. For example, double-glazed windows installed in 2020 are exchanged for triple-glazed windows at the end of their lifespan in 2040 to achieve the intended performance in 2050.

## **6. Conclusion**

The chapter has introduced the concept of future-proof design and integrated implementation roadmaps towards the step-by-step achievement of zero-carbon performance in 2050. The application of these concepts has been discussed on the level of governance and the level of single building projects as tools for goal setting and strategic development of future-proof building designs. While on building level, components of the building and energy concepts are addressed in a renovation roadmap; on the higher international, national, municipal and building sector layers, support schemes for research, technology development, capacity building and financial support are introduced in an implementation framework towards zero-carbon building performance. Especially for rapid construction activity in developing countries but also the existing building stock in developed countries, the future-proof design approach, supported by tools such as the DGNB framework for climate-neutral building stock or the individual renovation roadmap (iSFP), can be instrumental in overcoming inherent individual market barriers.

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## References

- [1] Fisch MN, Wilken T, Stähr C. EnergiePlus Gebäude Und Quartiere Als Erneuerbare Energiequellen. 2012. p. 328. ISBN: 9-783000-391675
- [2] Schwede D, Lu Y. Potentials for CO<sub>2</sub>-neutrality through energy-retrofit of the existing building stock in 26 cities in China. *Procedia Engineering*. 2017;**198**:313-320. DOI: 10.1016/j.proeng.2017.07.088
- [3] Hermelink A, Schimschar S, Offermann M, John A, Reiser M, Pohl A, Grözinger J. Comprehensive Study of Building Energy Renovation Activities and the Uptake of Nearly Zero-Energy Buildings in the EU—Final Report. 2019. Available from: <https://ec.europa.eu/energy/en/studies/comprehensive-study-building-energy-renovation-activities-and-uptake-nearly-zero-energy> [Accessed: 04 February 2020]
- [4] Schwede D. Entwicklung des Gebäudeenergiebedarfs und Einsparziele in Deutschland und in verschiedenen Ländern in Asien. In: Lozán JL, Breckle S-W, Grassl H, Kuttler W, Matzarakis A, editors. *Warnsignal Klima: Die Städte*. 2019. pp. 255-262. Available from: [www.klima-warnsignale.uni-hamburg.de](http://www.klima-warnsignale.uni-hamburg.de)
- [5] Schwede D. Climate-adapted material research for the socio-economic context of Vietnam (CAMaRSEC). In: *International Conference on Building Materials*, Hanoi; 31 October–2 November 2019. 2019
- [6] Fisch N, Möws B, Zieger J. *Solarstadt: Konzepte, Technologien, Projekte*. Kohlhammer; 2001. ISBN: 3-17-015418-4
- [7] Phaal R, Farrukh C, Probert D. *Roadmapping for Strategy and Innovation Aligning Technology and Markets in a Dynamic World*. University of Cambridge, Institute for Manufacturing; 2010. p. 240. ISBN: 978-1-902546-82-7
- [8] Rockström J, Gaffney O, Rogelj J, Meinshausen M, Nakicenovic N, Schellnhuber HJ. A roadmap for rapid decarbonization. *Science*. 2017;**355**:1269-1271
- [9] Tapia O. Technologietransfer und umgang mit technologie. In: *TRIALOG Zeitschrift für Planen und Bauen in der Dritten Welt*, TRIALOG 25. 1990. pp. 18-20
- [10] Braune A, Geiselmann D, Lemaitre C, Oehler S. Framework for carbon-neutral buildings and sites. German Sustainable Building Council (DGNB); 2018
- [11] DWD. Ortsgenaue Testreferenzjahre von Deutschland für mittlere und extreme Witterungsverhältnisse, Bundesamt für Bauwesen und Raumordnung (BBR) durchgeführt vom Deutschen Wetterdienst (DWD). 2016. Available from: <https://www.bbsr.bund.de/BBSR/DE/FP/ZB/Auftragsforschung/5EnergieKlimaBauen/2013/testreferenzjahre/start-node.html> [Accessed: 07 February 2020]
- [12] BMW. Handbuch für Energieberater Anleitung mit Tipps und Tricks zur Umsetzung, Bundesministerium für Wirtschaft und Energie (BMWE). 2017. Available from: <https://www.bmwi.de/Redaktion/DE/Publikationen/Energie/handbuch-fuer-energieberater.html> [Accessed: 10 February 2020]
- [13] DOE. DOE Zero Energy Ready Home Program, US Department of Energy. 2020. Available from: <https://www.energy.gov/eere/buildings/zero-energy-ready-homes> [Accessed: 11 February 2020]